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SOIL AND WATER CONSERVATION ON THE FARM

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ABSTRACT

Effective management of soil and water resources is one of the greatest challenges facing a farm operator today. Although extending the cropping system has been shown to reverse the trend of land degradation, the success of this practice is dependent on soil water conservation by improved tillage, snow management and snowmelt enhancement practices.

Equally important is the management of surface water supplies. The control of surface run-off by a combination of engineering and agronomic practices can lead to improved soil water storage and erosion control. Excess surface water can be more effectively retained for subsequent use by control of seepage and evaporation. Slough consolidation also plays an important role in the management of surface run-off. By reducing off-farm drainage, the negative impact on ground-water recharge is reduced, while making surface water available for irrigation and wildlife habitat.

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INTRODUCTION

Climate change is expected to have a substantial impact on Canadian agriculture (AES Factsheet, 1986). Alterations in regional and seasonal rainfall and evaporation patterns are expected to place higher demands on the management of soil and water resources. Increased severity and frequency of drought may cause accelerated soil degradation and erosion resulting from increasd moisture loss.

Extending the cropping system restores the organic matter and subsequently reduces erosion. However, the yield variability by the system, due to lack of moisture, has limited acceptance of this practice. The answer appears to be in the adoption of more efficient moisture management systems, such as improved tillage practices combined with better snow management.

Climate change may also impact surface water supplies due to increased evaporation caused by warmer temperatures and a possible decrease in precipitation. Evaporation and/or seepage control adapted to farm-scale situations may become necessary. Other sources of surface water supplies such as prairie sloughs must be managed to optimize the conservation of these resources.

This paper will review various water conservation practices on the farm. Some of these include tillage and snow management practices to improve soil moisture reserves. Management of surface water supplies by run-off water control, evaporation and seepage control and slough consolidation will also be reviewed.

TILLAGE PRACTICES

Summerfallowing for wheat production represents the single most important cultural cropping system on the prairies and in the western U.S.A. (Greb et al., 1974,Johnson, 1980). Although it has been used successfully in a cereal production system, it is considered to be relatively inefficient with respect to water conservation and subsequent water use (deJong and Steppuhn, 1980). Conservation efficiencies for the 21-month fallow period drops from over 20% in the Brown and Dark Brown soil zone to just over 10 % in the Black soil zone and less than 10% in the Dark Grey and Grey soil zones (Table 1). Adoption of new chemical weed control, minimum and zero tillage practices have improved fallow efficiencies to as high as 45% (Greb 1979).

Table 1. 21-month conservation efficiency for fallow by soil zone (from de Jong and Steppuhn 1980)

Soil zone	Efficiency (%)
Brown and Dark Brown	> 25
Black	> 10
Dark Grey and Grey	< 10

However, having improved the fallow efficiencies, it is important to recognize that stored water must be used effectively in order to control the problem of soil degradation. A comparison of cropping systems (Table 2) indicates a spring-wheat fallow system only utilizes 30% of the stored water compared to 80% for the continuous cropping system (Black and Siddoway, 1976).

In order to stabilize production during the "dry" years, the question then remains, " What are the alternatives to summerfallowing ?"

Table 2. Water use efficiency of precipitation as influenced by cropping systems (Black and Siddoway 1976)

Cropping system	Water use efficiency (%)
Continuous	80
Spring wheat - winter wheat - fallow	50
Spring wheat - fallow	30

SNOW MANAGEMENT

Research has shown that extending the cropping system can increase the organic matter in soils. However, continuous cropping increases the risks of poor yields in dry years and so might not be a practical alternative for farmers facing high annual production costs. This is particularly true in the Brown and Dark Brown soil zones of the prairies. Retaining snow where it falls improves the potential of water conservation and thereby soil conservation. It is often said that "manipulation of snow cover offers the greatest potential for increasing available water for dry land crops on the Canadian prairies" (Rennie 1979). Snow management to increase soil water conservation requires that snow be trapped, distributed and held on the fields until the crop is grown. This also means that in melting, the water should have good opportunity to enter the soil rather than be lost to run-off.

Noncompetitive Barriers

Stubble management is the most viable snow management practice for the prairies because of the type of crops grown and the nature of cultural operations. The most popular methods include tall stubble, alternate height stubble, and trap strips.

Tall stubble:. Studies on the use of tall stubble for trapping snow were conducted by the Division of Hydrology at Saskatoon and Port Reeve (Nicholaichuk et al 1985). Based on an average stubble height differential of 6 cm between conventional stubble height and tall stubble height suitable for straight combining, the net increase in snow water equivalent available for soil recharge was 1.6 cm. Consequently, the amount of moisture that can be gained by utilizing "tall" stubble is limited by the height of stubble.

Alternate-height stubble: Swathing at alternate heights is a form of snow management that has been investigated for a period of 13 years at the Swift Current Research Station (Nicholaichuk et al. 1985). Treatments consisted of alternately swathing the wheat crop at two different heights using a self-propelled swather. The heights are dependent on the crop stand condition. The control consisted of wheat that was swathed at a uniform height.

The average depth of snow trapped by non-uniform stubble was 4 cm or 22% more than on the uniform stubble. Additional soil water increase from trapped snow was 1.4 cm or 23% greater indicating an approximately linear relationship between snow depth and moisture equivalent.

Trap-strips: A concept developed in 1979 consists of leaving a strip of tall standing stubble that acts as a barrier to trap snow on stubbled fields. Only 3 years of study have been devoted to this trap system of snow management. The clipper system tended to trap more snow than the deflector attachment. The clipper system left more erect standing stubble that tended

to provide additional turbulence for compacting snow within the tall strips of tall standing stubble. On the average, the clipper system trapped 15 % more snow than the deflector system. In addition, the clipper system trapped 39 % more snow compared to the uniform stubble check.

Trap strips, either the deflector or clipper type, were on average 20 and 36 % more effective in trapping snow over the same three year period compared to the alternate height stubble method. In comparing the two systems, the trap strip offers a greater potential capacity because of the physical configuration.

In terms of soil water storage, the trap system by either the deflector or clipper method increased the stored water by as much as 2.2 and 3.6 cm respectively. This increase in water storage represents an intake efficiency of 62 % for the deflector and 74 % for the clipper compared to 38 % for the check. In other words, the intake efficiency for the clipper is nearly double the control. In comparison to the alternate stubble heights the intake efficiency was found to be considerably higher than either control or the alternate height system. This suggests that a barrier created by the clipper system may act as a heat sink during the thaw period resulting in increased moisture trapping.

Competitive Barriers

The Tall Wheat Grass barriers concept developed in northern Montana (Black & Siddoway 1976) and later studied at Swift Current, has been found to be effective for trapping snow (Nicholaichuk et al 1985). Barriers consist of tall wheat grass planted in single or double rows spaced 9 m to 15 m apart. The grass barrier offers a greater potential for trapping more snow than the non-competitive types. This is mainly attributed to the fact that the tall wheatgrass provides a barrier that is a metre in height or more. Five years

of data suggest that the barrier system traps approximately twice as much snow as the uniform stubble.

Not only did the barrier system trap offer an opportunity to trap more snow, the net increase in water stored was 73% greater than the control. Results to date are similar to those reported by Black and Siddoway (1976).

TILLAGE PRACTICES TO ENHANCE SNOWMELT INFILTRATION

Data collected to date suggests that existing techniques are successful in trapping snow. However, 13 years of data by swathing at alternate heights also suggests the benefits that can be attributed to snow management are highly variable due to reasons given earlier in this paper. To this end, exploratory studies have been initiated to determine whether snowmelt infiltration can be enhanced. (Nicholaichuk et al. 1985a, Gray et al. 1985).

Utilizing a conventional subsoiler and a Paraplow (Pidgeon 1983), trial experiments were initiated to determine whether such tillage practices were beneficial on stubble land on which trap strips were prepared. Preliminary data suggests that "naturally-cracked" heavy clays and "ripped" subsoiled soils offer high potential for soil water augmentation by snow management practices (Gray et al 1985). On average, depending on the available snowcover water equivalent, water intake in fractured soils was in the order of 6.7 to 7.5 times the amount of infiltration to undisturbed stubble.

From the one-year study at Swift Current, Saskatchewan (Nicholaichuk et al 1985a) subsoiling or paraplowing between the strips of tall standing stubble did not appear to reduce the depth of snow trapped. The practice of 'Paraplowing' did have a beneficial effect of enhancing snowmelt infiltration when compared to the control. The benefits attributed to these types of

tillage practices are related to the amount of snow entrapped. On uniform stubble, when a smaller amount of potential stored moisture was trapped, tillage had a detrimental effect on the amount of water that was stored.

Studies to date suggest that water augmentation practices by deep ripping or paraplowing appear to be beneficial provided sufficient snow is trapped by standing stubble. Studies conducted by Gray et al. (1984, 1985) indicate that "naturally-cracked" heavy clay soils are ideal for snow management practices since they ensure that water from trapped snow will be stored in the soil for subsequent crop use. A co-operative study on snow management and snowmelt infiltration funded under the Canada/Saskatchewan Economic & Regional Development Assistance Program is currently examining in more detail the optimum depth and spacing of various tillage practices to enhance snowmelt infiltration that are ecomically beneficial (Nicholaichuk et al. 1988).

RUNOFF WATER CONTROL

In the prairies, rapid snowmelt on frozen soil is a major flood hazard and results in the loss of much valuable water. Analysis of precipitation and run-off volumes at watersheds located in southern Saskatchewan, at Swift Current and Davin, indicates that over 85% of the total run-off comes from snow (Nicholaichuk, 1967). Observed run-off at Swift Current ranges from nil to a maximum of 4.8 cm with a 32-year average of 1.7 cm.

Controlling run-off requires a combination of engineering and agronomic systems. Some methods include the division of larger fields to reduce water avalanching, using straw mulches to soften raindrop impact and improve water intake, physically restraining solid movement with surface roughness and miniature dams, planting furrows on the contour, strip cropping and grassing waterways.

Use of engineering systems to control water implies earth moving of some kind. Land levelling, lagoon enlargement, waterway flood pans and terraces all have shown promise in water control (Mickelson, 1965, 1966, 1968 and 1970). In most cases, there is a trade-off between earthmoving costs and exposure of less fertile subsoils as weighed against better water utilization and higher crop yields.

Land levelling is a technique generally used to spread water uniformly over fields and increase the time of infiltration. Levelling may frequently involve some land grading to permit uniform flow of the water across a level field to provide drainage at non-erosive velocities.

The objective in levelling dryland is to retain all precipitation, eliminate run-off and increase soil water storage. Over a five year period, at Akron, Colorado Mickelson et al. (1965) have shown that level benches without a contributing area averaged 4.3 cm more available water annually than the non-levelled area. When precipitation averaged 24 cm, levelling showed no increases in grain yields. When precipitation averaged 36 cm the levelled areas yielded 737 kg/ha more wheat than the non-levelled areas. Though dryland levelling has shown some potential for improved water management on semi-arid lands, its economic feasibility is questioned because of the variability of precipitation, high cost of levelling and fertility problems created by deep cuts and fills.

Potholes are common on the prairies. Many are old buffalo wallows, small drainage slumps in the original landscape, or wind blow-outs from former droughts. Soils in these potholes are generally heavy textured such as silty clay loams. Soil fertility is high, being rich in nitrogen, organic matter and phosphorus.

Rehabilitation of potholes is relatively simple (Mickelson and Greb, 1970). Potholes can be levelled by moving lighter textured soils from the edges to and across the bottom. The surface area of the levelled pothole is more than doubled which provides better distribution, impounded run-off and increases water intake. The additional water received in a levelled pothole with rich soil will usually permit continuous cropping of forage crops or high-yield domestic grasses and legumes with yields more than double that around the outside fringes of the pothole. Cost may be amortized in a 4 to 6-year period from the increased yield.

Terraced hillsides are as old as recorded history. Terraces were of little interest to the North American farmer until 1940, when water erosion became a serious threat to sloping humid farmlands (Greb, 1979). Hence, the use of various terrace designs in semi-arid lands is a recent innovation.

The original terraces were a ridge-type, constructed on the contour to control erosion. Concave channels above the ridge can either be level or graded to allow drainage of excess water at non-erosive velocities. The conventional ridge-type terraces were later modified to a bench-type terrace to effectively control erosion and to provide uniform distribution and efficient utilization of water intercepted by crops in a levelled bench.

On semi-arid lands, the bench terraces are constructed level throughout their entire length and width because intercepted water is seldom excessive. The bench is levelled to a zero grade in all directions with a wide elevated ridge on the lower side to retain the impounded water. The ratios of contributing area to level bench area varied from 2:1 to 4:1, depending upon precipitation probability, slope and soil type.

Bench terraces have been shown to be an effective means of increasing forage production (McMartin et al., 1970) as a result of improved water management (Table 5).

Table 5. Alfalfa production at Mandan, North Dakota (from Martin et al., 1970)

	Yield (kg / ha)
Unbenched slopes	2696
Benches without contributing area	6291
Benches with contributing area	6740

Evaporation and Seepage Control

Losses of surface water supplies due to evaporation and seepage can have significant impact on rangeland utilization. It is recognized that range utilization patterns are dependent on the availablility of water supplies. Consequently, the assurance of a reliable potable water supply is of prime importance to range management and soil conservation.

Low cost seepage control methods for farm reservoirs were examined by Nicholaichuk (1978). Use of organic liners combined with soda ash or bentonite can produce a rapid and acceptable method of reducing seepage. Other methods such as plastic or butyl liners are more costly but do have a limited life expectancy.

Evaporation losses from farm ponds and reservoirs can reach as high as 900 mm in any one year (Durrant 1959). Methods of reducing evaporation losses have been examined by Nicholaichuk (1978). Monomolecular films can reduce the

evaporation loss by 18% . Rafts made of light-weight concrete or Styrofoam panels have also been proved to be an effective alternative. However the relatively high cost and life expectancy does not make these alternatives attractive.

Water Harvesting

Methods of water harvesting have been examined by Mickleson (1973) at Akron, Colorado. Performance characteristics and durability of various materials that render a confined area impervious have been examined. Water harvesting efficiencies as high as 70% have been observed. The major deterrent to the adoption of these practices is cost.

SLOUGH CONSOLIDATION

Sloughs, estimated to number from 6 to 8 million south of the 54th parallel in the prairie provinces (Munro 1967), represent a substanial water resource that is being threatend by drainage resulting from pressure to increa considered, a number of factors must be considered. One is the possible effect drainage may have on the supply of groundwater. Sloughs can be divided into two broad groups: recharge or discharge types. The recharge slough contributes to groundwater recharge and is more common than the discharge slough.

Slough consolidation provides an opportunity to preserve groundwater recharge while allowing producers to expand their land base for production. There are a number of methods by which sloughs can be drained or consolidated. These include the use of a drainage ditch and gate, drainage ditch and pump and drainage by irrigation (Nicholaichuk, 1982).

Drainage ditch and gate

With this method of drainage only a control gate and drainage ditch are needed. If a dyke is used to increase the amount of land flooded, the gate is placed in the dyke. Water is held in the slough until the frost has gone out of the ground so that the soil can absorb as much water as possible before the gate is opened. Gravity drainage by ditch is suitable if the surrounding land is not too high and a water course is readily available.

Drainage ditch and pump

This method can be used in areas where it is not practical to dig a drainage ditch deep enough to drain. It may be necessary to construct a ditch that is higher at the bottom and pump the water into the drainage ditch. In place of a control gate, a pump can triple the cost of drainage.

Drainage by Irrigation.

If small or shallow sloughs are far from a drainage channel, it may be more economical to drain sloughs by irrigating land surrounding the slough. Since it is assumed that the surrounding land is higher than the water level, a pump is needed for the irrigation methods.

A number of questions arise when considering consolidation of sloughs. For example, will salinity increase as a result of increased hydraulic presure at a point source? To this end, a demonstration project in the Peace River Region of northern Alberta was initiated to test the technical and economic feasibility of storing drainage water on farms as an alternative to building conventional outlet ditches (Jensen and Wright, 1987). In addition to consolidating run-off and drainage water in a pond, the project incorporated the needs of wildlife habitat. There is still a need to understand the hydrology of wetlands and the implications of slough consolidation.

SUMMARY

Effective management of soil and water is one of the greatest challenges faced by the farm operator of today. Researchers and producers alike are well aware that land degradation is linked to the utilization of soil water. If climate change were to become a reality, problems of soil and water will be severely aggravated.

Extending the cropping system has been shown to be the answer for restoring the organic matter and subsequently reducing erosion. However, the yield variability of the system has to be reduced if it is to become acceptable. The answer appears to be in the adoption of more efficient moisture management systems. Adoption of practices such as minimal and no tillage, chemical fallow, snow management, use of winter crops (i.e. wheat and fall rye), improved fertilizer practices and management of crop residues are some of the answers to improved soil and water managment.

The management of surface water supplies will require more attention than ever before. Run-off control measures that were originally introduced in the thirties will have to be revisited.

Problems of seepage and evaporation control should be addressed to ensure the preservation of adequate supplies particularly during periods of drought. Slough drainage should be substituted by slough consolidation in order to ensure that groundwater supplies are recharged and that surface supplies are maintained.

These are some of the important issues of the day. In some cases, technology is available to address these issues, for others, there is a need for more research.

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